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Ljungberg, Jonas

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Jonas Ljungberg[*]

Abstract: Does education cause economic growth, or is it the other way around that economic growth causes education? Certainly the process is cumulative, yet whether it is possible the determine one of the sides as dominant, is a debated issue. This paper explores that relationship for Sweden from the early days of industrialization until recently. It sketches the expansion of compulsory, secondary and higher education. Contrary to previous research concerning education in Sweden, no support is found for the hypothesis that demography, variations in cohort sizes, can explain changes of enrolment in voluntary education. On the basis of an analysis of time series, the paper argues that enrolment in higher education has been a causal factor for labour productivity in manufacturing, and thereby for economic growth, in Sweden since the late nineteenth century.

I Introduction

At least since the early years of the discovery of the residual in the growth function has part of this residual been attributed to education. More recently for example Barro (1991) and Barro and Sala-i-Martin (1995) have sought to confirm such a causality from education to growth for a cross section of countries in the post-war period. However, other findings query if not the causality might run in the other direction, from economic growth to more education.

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[*] Address all communications to Jonas Ljungberg, Department of Economic History (Lund University), P.O. Box 7083, S-22007 Lund. E-mail: jonas.ljungberg@ekh.lu.se

That is the presumption of Diebolt and Monteils (2000) from an analysis of long-term data for Germany. Re-visiting the post-war cross country data set, used by Barro and others, Bils and Klenow (2000) confirm the correlation between schooling enrolment in 1960 and the subsequent economic growth, but claim that the main direction of causation was from economic growth to education. Basically their argument is that countries with high enrolment in 1960 did not display a faster subsequent growth in human capital or technology why these factors should have contributed less to economic growth. However, one may also hold that since it is the stock of human capital that affect economic growth, it is the level and not the rate of change that is relevant in this perspective.

Moreover, it is ambiguous to draw conclusions about the nature of causation from cross-sectional data. Causation considers time and should be analysed as historical processes, whether from time series of quantitative data or more qualitatively. A comparative approach is certainly superior if one looks for general conclusions, yet the aim of the present paper is more limited. It takes a look at the connection between Swedish economic growth, or more specifically, the growth of labour productivity in manufacturing, and the expansion of education since the last third of the nineteenth century.

Even if there is a broadly shared view that human capital is important for the long term economic performance, as argued by, for example, Lars Sandberg (1978, 1982), it is not quite obvious why. Such a positive role of human capital has also been disputed with the assertion that Taylorism and Fordism have deskilled labour during the twentieth century (Braverman 1974). It could thus seem as if a complementarity between technology and skills, or human capital, is a recent phenomenon, originating in the third industrial revolution and computerization. However, as Goldin and Katz (1998) point out in an important article, the technology-skills complementarity can be traced back in history. The technology of the second industrial revolution around the turn of the century 1900 presupposed not only mass production workers, with less skills, but also workers that managed installation and maintenance of the new manufacturing technology. These latter workers must have more skills, and Goldin and Katz (2001) associate the expansion of high schools in the U.S. during the period 1910-1940 with the growth of the related industries.

Yet, it can be doubted that the distinction between production work and installation-maintenance work bears all the way to explain the complementarity between technology and skills. The Swedish industry thus shows an alternating pattern between periods when relatively more skilled labour, and periods when relatively more un-skilled labour, has been in demand (Schön 1994, 1998). For example, this pattern can explain the variations in the speed of the reduction of the gender gap in wages of manufacturing over the period 1913-1990 (Svensson 1995). According to this hypothesis, the weight of the technology-skills complementarity should be related to the long swings in Swedish economic development. During phases of transformation and structural change relatively more skilled labour has been required, not only for installation and maintenance but for new tasks in different sectors and at different levels of the economy. Such phases have characterized about twenty year long periods, interrupted by equally long phases dominated by stability and rationalization. During these rationalization phases, the demand for skilled labour has slackened whereas the demand for unskilled labour has increased.

The long swings might explain the variations in earnings differentials between white collar and blue collar labour, although the variations over most of the twentieth century have moved around a trend of diminishing differentials (Ljungberg 2000). Thus there should be different forces at work, exposed on the one hand in the about twenty year long swings, and on the other hand as a secular trend of a diminishing premium on grades of human capital. The trend could be taken as an argument for the Braverman thesis, but a more fruitful reasoning was presented by Tinbergen (1975). Taking account of the technology-skills complementarity he perceived the income distribution as an outcome of a race between technology and education, and found that over the long-term it had been won by education. Thus, the increased demand for skills has been outgrown by the expansion of education that has more than proportionally increased the supply of skills.

The reasoning started above with the impact of human capital on productivity, and turned to a discussion of earnings differentials. The connection is of course the presumption that earnings reflect productivity. The long-term growth of productivity has resulted in an increase of earnings, relatively most for blue collar labour which also could be seen as an increase in the general level of human capital. The total stock of human capital is influenced both by the general level of the labour force and of the amount of specialists in the labour force. Education, measured for example through enrolment, add to the stock of human capital and it is reasonable to believe that a larger contribution will show up with a time lag as an increase in the growth of productivity, as well as reductions later on will result in slower productivity growth.

However, an increase in productivity may also have an effect on earnings and if human capital is relatively better remunerated, then education will seem more attractive and an increase in enrolment of voluntary education will follow. Thus a cumulative process will evolve. If there has been such a process in twentieth century Sweden, and if it is possible to disentangle which factor, productivity or enrolment, that has had the upper hand, is the issue below.

The limitation to productivity should be motivated briefly. The rate of change in GDP is the measure of economic growth, yet GDP is a big aggregate influenced both by the quantity of inputs in production, their quality as well as their composition. Education is assumed to have an impact on the quality of labour, either through increasing the level of human capital within a given composition of the economic sectors, or in combination with structural change that increases the knowledge intensive sectors. Accordingly, education should influence labour productivity. Due to measurement problems and data constraints, productivity here is confined to blue collar labour in manufacturing for which Swedish data are available since 1890 (Schön 1990b).

One might, of course, dispute the impact of education on human capital as too a narrow comprehension, restricted as it is to the individual, and claim that education has a much broader influence on society. Education thus has an influence on social capital and thereby a more compound influence on what Abramowitz denominated social capability for economic growth.[2] Here we approach, however, what earlier economic historians discussed as differences in culture which cannot, regardless of their importance, be captured in quantitative terms. In the final analysis, though, education should have an impact on productivity, whether conveyed through human or social capital or culture. The limitation to productivity therefore seems reasonable.

The next section of the paper draws a quick outline of the expansion of education in Sweden, and relates it to demographic change. The third section explores the relationships between enrolment in education and productivity in manufacturing. Some econometrics is used, yet presented with the aim to make both the data and the analysis more transparent also for less technical readers. Section five concludes the paper.

II. Expansion of education in Sweden

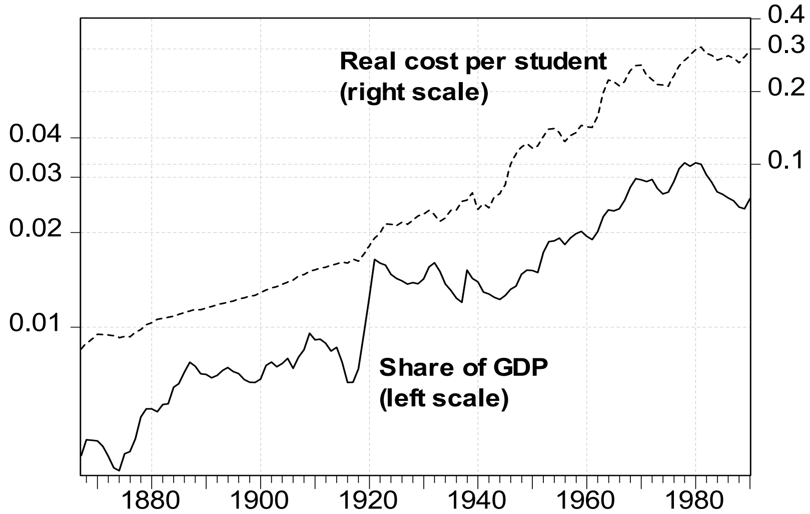
It is well known that literacy was high already before industrialization in Scandinavia. Moreover, recent research emphasizes that the ability to write was important for the commercialization of agriculture that preceded industrialization (Nilsson, Pettersson and Svensson1999).

Superficially this seems to confirm the Sandberg thesis. According to Sandberg (1982), however, Sweden was an "impoverished sophisticate" by mid-nineteenth century, and first during industrialization the extravagance of literacy bore fruit. Yet, both views share the emphasis on human capital even if they date the onset of economic development differently.

The early literacy had not its origin in compulsory schools. In Sweden there was a tradition of domestic schooling and it also took several decades after the introduction of compulsory school in 1842, before the great majority of children went to school more than casually. In the 1870s compulsory school was extended from four to six classes. This marked the breakthrough of primary schools in Sweden, as exposed by its rapidly increasing share in GDP (see figure 1).

[2] Abramowitz (1986, 1995). About the expansion of secondary education and social capital in the U.S.A., see Goldin and Katz (2001).

Figure 1 : Contribution of primary schools to GDP, share in current prices, and cost per pupil, thousand crowns in constant prices of 1910/12 , five year centered moving averages.



Note: The contribution is measured as the sum of salaries and investments while expenditures on intermediary costs are excluded. Investments 1867-1917 are provisionally extrapolated from their proportion to salaries in 1918-23. The data used here and elsewhere in this paper will be made available in Ljungberg (forthcoming).

Figure 1 displays the contribution of compulsory education to GDP as conventionally measured, that is, at factor cost. Thus it is the sum of salaries and of investments, whereas books and other intermediate costs are excluded. Compulsory school first included only primary schools, yet with the passing of time lower secondary school, that is, classes 7-9, also became included. Around 1870 four years in primary school were the norm, extended to six years a decade later, and seven years in the interwar period. After World War II compulsory school was successively extended and in 1970 everyone spent nine years in school.

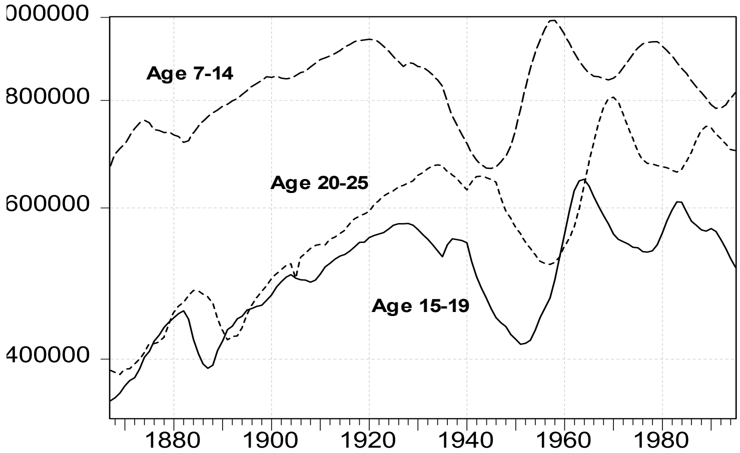
There are three components behind the increase of primary, or compulsory, education in GDP. One is the increase in the length of schooling as just outlined, provided that schools were given more resources. Schools can be given more resources for other reasons, for example, when teachers' salaries are elevated, and if that increase is larger than the percentage growth of GDP, the share in GDP will increase. However, that is only the case when current prices are used, since when measured in constant prices the elevation of salaries will not show up as an increase of resources. The third component is demographic change which influences the quantity of throughput in education.

The series showing the cost per student in Figure 1 is also composed of investments and labour cost, whereas intermediate consumption is omitted. Moreover, that series has been deflated into constant prices (of 1910/12) and divided by the number of students in compulsory school. Even if the similarities between to two curvatures strike the eye, there also are important differences which inform about the components in the development. Compulsory schooling as a share of GDP increased significantly in the 1870s and 1880s, and around 1920, without a corresponding change in real cost per student. At the first instance there was a rapid increase of the number of teachers as well as of teachers' salaries. Real cost per student increased only slowly, according to the longer trend, since due to the lengthening of compulsory schooling, enrolment increased almost correspondingly. The second rapid increase in the share of GDP, is explained by the fact that teachers' salaries more than trebled 1917-1920, whereas GDP, in nominal terms, not even doubled. However, the increase in real cost per student is much less dramatic, in these years, since the blow-up of nominal salaries is nullified when converted to constant prices.

From 1920 to 1944 the two series move in opposite directions, and the divergence is explained by the decrease in fertility in the interwar period. Note that the real cost per student accelerated a couple of years before the cohort sizes changed the trend of the share in GDP, thus indicating a political will of the time to spend on schooling. Note also the concomitant drop in both series during the first half of the 1970s, this time indicating a political will to save money instead of letting the, already passed, ease of demography enhance investments in human capital. Between 1970 and 1975 the volume of investments (in constant prices) in the infrastructure of compulsory schooling was halved. The latter part of the 1970s saw a recovery, but again in the 1980s, when the transformation of the third industrial revolution demanded more human capital, school investments fell and also labour input stagnated.

As far as compulsory education is concerned, there was a secular expansion that was faster than the economic growth. Over the whole period, from 1867 to 1990, compulsory education increased from less than 0.5 percent of GDP to 2.6 percent. Yet, the highest share, 3.4 percent, was reached in 1978 and the following decrease was only partly due to smaller cohort sizes. If we apply yet another measure of compulsory education and adjust the share in GDP for student numbers, the peak actually occurred already in 1969. Measured in that way, more than the whole expansion took place during three periods: 1874-1888, 1917-1921, and 1961-1969. It is a remarkable fact that the expansion of education, over what can be explained by a proportional growth in GDP and by population growth, occurred during three short periods together embracing three decades, during a period of twelve decades.

Figure 2 : Cohort sizes, number of persons in three age groups 1867-1995.



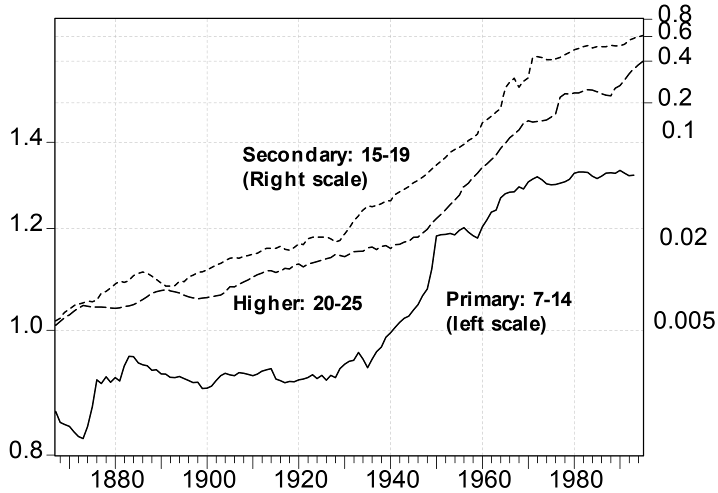
Source: Computations from Wilmoth (2001).

Figure 2 highlights the demographic component in the expansion of education. Although cohort sizes increased up to the interwar period, bad harvests in the late 1860s had caused a demographic setback that around 1880 resulted in a decrease of those aged 7 to 14. It was precisely in these years when primary education was given more resources and enrolment substantially expanded. After 1920 a sharp drop in fertility reduced numbers aged 7 to14 with almost 30 percent until 1945. The post-war demography exhibited a cyclical pattern with two peaks, for those aged 7 to14 in 1958 and 1979.

Figure 3 adds to the picture by giving the enrolment ratios for primary, secondary, and higher education. Here primary education is homogenously defined, including lower secondary schools and classes up to ninth year that became compulsory in the post-war period. However, enrolment adequately should be compared with cohorts up to 16 and not just to 14. That is why the primary ratio is hovering between 130 and 133 percent from 1970 onwards. Two periods of expansion fall out: in the 1870s, and from the 1930s to 1970. As regards the effects on the cost of education, the latter period of expansion initially counteracts the demographic decline, and then in the post-war period reinforces the demographic increase.

Furthermore, it is notable that the trend of enrolment in higher secondary education bends upward in 1930, while the take off for higher education had to wait until 1950. These breaks of trends cast doubt on the Easterlin effect. According to the Easterlin effect, the more intense competition for careers in

Figure 3 : Enrolment ratios in primary, higher secondary, and higher education.



Note : Definitions, see text!

bigger cohorts induces higher enrolment in education, and the lesser competition within smaller cohorts should lead to lower enrolment (Easterlin 1987, Ohlsson 1986).

A comparison with Figure 2 actually indicates that the age group relevant for higher secondary education started a long decline about 1930, and that the age group relevant for higher education was still on decline in 1950. It might be that the discussion has too much focussed on the very conspicuous expansion of education in the later post-war period, when the huge breeds of the 1940s entered secondary and higher education. Despite decreasing cohort sizes, however, enrolment in higher secondary education accelerated from 1930 and in higher education from 1950.

Around 1970 enrolment found a plateau, yet in the later 1980s expansion resumed, in particular of higher education. From 1988 to 1995 enrolment in higher education increased from 23 to 40 percent, and from 52 to 61 percent in higher secondary education. The definition of higher education became broader than previously from 1977 onward, and several programmes that previously were defined as vocational training became administered by university colleges. This change of definition actually hides a part of the decrease in traditional higher education during the 1980s. So even if there was a substantial increase in enrolment after 1988, it started from a lower level than shown in figure 3.

A quantitatively important group, yet difficult to define, that has been excluded from higher education, as defined here, is students at the public school teachers' colleges (*seminarier*). Before World War II these teachers normally graduated about an age of 22, after entering the college at 18 without any previous secondary education. Before 1920, the size of this group corresponded to 30 percent of the students in other higher education, declining to 20 percent in the interwar period and a mere 4.4 percent in 1942. This decline was obviously an effect of the reduced number of pupils in primary school, caused by the interwar fertility decline. The new expansion of primary education led also to a boom for the teachers' seminars. In 1949 their numbers corresponded to 40 percent of the students in other higher education. Were they included in the enrolment in higher education, the trend of enrolment would have bent already in 1945, thus reinforcing the critical argument above about the Easterlin effect.

To summarize: Compulsory education had a short period of expansion in the 1870s and 1880s, and a long expansion from the late 1930s to 1970. Higher secondary education expanded in four decades from 1930, and higher education in two decades from 1950. The 1970s and 1980s were a period of stagnation. In the late 1980s expansion resumed in higher secondary and higher education, though investments or expenditures are not considered.

III. Does education increase productivity?

The basic problem addressed here is the interrelation between productivity in manufacturing, which has been an important component in Swedish economic growth, and the expansion of education, measured as enrolment. The aim is, however, not to build a full-fledged model that can make a quantitative estimate of the contribution of education to productivity change but a more modest one. Such an estimate must be based in an assumption about causality and the aim is, precisely, to explore the relation between education and productivity and to identify the possible main direction of causation.

If there is any causal interrelation, one should expect one of two types of correlation. Either will productivity change systematically show up a certain period after a similar change in enrolment, when the former students are integrated in the labour force. This may indicate that education causes economic growth. Or, on the contrary, will changes in enrolment systematically show up a certain period after a similar productivity change, indicating that economic growth fosters expansion of education. There may also be a cumulative process with both sides acting as cause and effect, either with one side persistently dominating or with the dominating side changing over time.

Table 1. Granger tests on productivity of blue collar labour in manufacturing and enrolment in education, 1890-1990

Null Hypothesis: (G.C.=Granger cause)	Period	Lags: 3 yrs P-value	Lags: 5 yrs P-value	Lags: 7 yrs P-value	Lags: 9 yrs P-value	Lags:11yrs P-value
E714 does not g.c. P	1890-1990	0.0981	0.2576	0.3006	0.2405	0.3418
“”	1890-1940	0.0450	0.1078	0.2659	0.1572	0.0985
“”	1950-1990	0.0002	0.0011	0.0002	0.0005	0.0039
P does not g.c. E714	1890-1990	0.5465	0.6836	0.8508	0.8884	0.8523
“”	1890-1940	0.1991	0.1428	0.5812	0.7344	0.9062
“”	1950-1990	0.0025	0.0015	0.0069	0.0074	0.0057
E1519 does not g.c. P	1890-1990	0.0179	0.0476	0.1103	0.1956	0.2144
“”	1890-1940	0.9383	0.8933	0.0640	0.2814	0.6786
“”	1950-1990	0.0062	0.0539	0.1522	0.1178	0.3060
P does not g.c. E1519	1890-1990	0.7820	0.2398	0.2991	0.4904	0.7649
“”	1890-1940	0.0732	0.1764	0.1452	0.0146	0.0417
“”	1950-1990	0.4087	0.1022	0.1038	0.2249	0.4522
E2025 does not g.c. P	1890-1990	0.0003	0.0016	0.0045	0.0097	0.0581
“”	1890-1940	0.0119	0.0083	0.0299	0.0771	0.1323
“”	1950-1990	0.0002	0.0007	0.0026	0.0173	0.0725
P does not g.c. E2025	1890-1990	0.5883	0.6310	0.9178	0.7259	0.5035
“”	1890-1940	0.0830	0.3105	0.8360	0.5934	0.6667
“”	1950-1990	0.9430	0.9965	0.9825	0.9971	0.6452

Note: E714 stands for school enrolment among those aged 7 to 14 years; E1519 those aged 15 to 19 and enrolled in higher secondary education; E2025 those aged 20 to 25 and enrolled in higher education. P stands for productivity of blue collar labour in manufacturing. All series are logged.

One simple way of finding if there is any such lagged pattern in pairs of time series is the Granger test. Provided that there is some path dependency in a time series, say enrolment in education, current values can be regressed on preceding values. The Granger test adds also the preceding or lagged values of another time series, say productivity, and indicates if these significantly add to the explanation of enrolment. Table 1 reports Granger tests on the logged values of enrolment in education and of labour productivity in manufacturing with different time lags and for different periods. The figures are the probabilities that the lagged values of the other series do not add to the explanation, and a figure of 0.05 means that the lagged correlation can be established with the conventional statistical significance of 95 percent. The Granger test says nothing about real causality but it may explore a time pattern that can reject, or fail to reject, causality. In the latter case there is said to exist a "Granger causality" which remains to be theoretically explained.

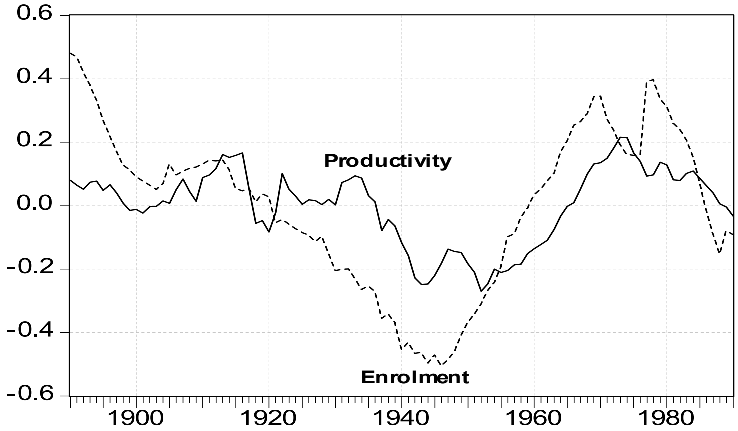
Another finding is that there was a mutual "Granger causality" between enrolment in compulsory education and productivity change during the second half of the twentieth century. Probabilities are very strong in both directions, though possibly stronger from education to productivity than the reverse. What can be concluded from this econometric finding? We know that compulsory school was prolonged from seven to nine years during the first two decades of this period whereupon enrolment found a plateau (see figure 3), and we also know that economic growth and productivity change slowed down from 1975. The Granger test in this case just seems to confirm what we already knew.

Concerning secondary education results are also weaker, yet indicate a "Granger causality" from enrolment to productivity change though not for the half century before 1940. An important conclusion from the tests, is that productivity change has followed upon change of enrolment in higher education throughout the twentieth century, and during the second half also upon change in enrolment in secondary education.

A further time series analysis shows that enrolment in secondary as well as in higher education are cointegrated with productivity in manufacturing, according to a standard test (Johansen). In other words, there are long-term trends in these series, yet there persists a constant relation between them, or, more precisely, variations around a constant relation. Assuming that these variations are movements around an equilibrium, econometrics prescribe that such relations should be analysed with an error-correction model. However, it seems to me that the information obtained from such a model will be based too much on short term behaviour, due to its reliance on first differences or annual change.

I have therefore proceeded in another way. The series have been detrended through subtraction from their quadratic trend. That reduced but did not completely erase the trends – there remained weak unit roots in the series. A graphical inspection, as in Figure 4, also shows the similar swings in productivity and enrolment, in particular when productivity is compared with higher education. It is clear that the series follow a similar pattern but from the graphical inspection it is not possible to judge if there are any systematic leads and lags. The Granger tests indicate that changes of enrolment in higher education have preceded productivity change and now it will be seen if the detrended series, where the swings are more emphasized, support or reject that result.

Figure 4 : Labour productivity in manufacturing and enrolment in higher education of 20 to 25 year old: residuals from quadratic trend, 1890-1990



Regressions were run with enrolment in secondary and higher education, respectively, and productivity changing place as X and Y:

$$Y_t = \text{constant} + \beta_1 X_{t-3} + \beta_2 X_{t-5}$$

That is, the detrended productivity series was regressed on enrolment in education three and five years earlier, and the reverse, enrolment was regressed on lagged values of productivity. Table 2 reports the results. At first sight it seems as if enrolment in higher education can explain 36 percent of the variation in productivity, and that the five-year lagged variable is clearly significant. However, as shown by the low Durbin Watson statistics, there is high autocorrelation, systematic variations that are not explained, maybe produced by the remaining unit root. A standard procedure to handle autocorrelation can be to add an autoregressive variable – which here produces brilliant R2 –values and cleans up most of the autocorrelation (the desired Durbin Watson statistics should be in the range 1.7-2.3 when there are three independent variables and 100 observations). However, also the five-year lagged enrolment loses its probability and all that remains is an autoregressive explanation. The same pattern is repeated when secondary enrolment, as well as higher education, are regressed on productivity. Only productivity regressed on enrolment in higher education, as seen from regressions (5) and (6), survive with acceptable probabilities when the autoregressive term is added. In this case we may conclude that the significance of the coefficients are not a spurious result of the autocorrelation. The exercise thus seem support the result of the Granger test: The hypothesis that higher education was a causal factor in Swedish economic growth during the century 1890-1990 cannot be rejected.

Table 2. Regressions with productivity and enrollment in education, 1890-1990

Dependent variable (regr. no.)	**constant**	**Indep. variable (lag)**	**Indep. variable (lag)**	**AR(1)**	**Durbin Watson**	**Adjusted R2**
P (1)	-0.0078 (P: 0.438)	**E1519(-3)** 0.1229 (P: 0.273)	**E1519(-5)** 0.2450 (P: 0.030)	--	0.19	0.36
P (2)	-0.0190 (P: 0.813)	**E1519(-3)** 0.0862 (P: 0.189)	**E1519(-5)** -0.0703 (P: 0.287)	0.9515 (P:0.000)	1.43	0.91
E1519 (3)	-0.0088 (P: 0.666)	**P(-3)** 1.3364 (P: 0.000)	**P(-5)** -1.0010 (P: 0.006)	--	0.15	0.12
E1519 (4)	-0.2113 (P: 0.524)	**P(-3)** 0.2319 (P: 0.181)	**P(-5)** -0.2288 (P: 0.183)	0.9728 (P:0.000)	1.56	0.92
P (5)	-0.0028 (P: 0.701)	**E2025(-3)** 0.2321 (P: 0.024)	**E2025(-5)** 0.1656 (P: 0.093)	--	0.25	0.66
P (6)	0.0059 (P: 0.816)	**E2025(-3)** 0.2409 (P: 0.003)	**E2025(-5)** 0.1782 (P: 0.028)	0.8562 (P:0.000)	1.52	0.92
E2025 (7)	-0.0203 (P: 0.325)	**P(-3)** 1.5751 (P: 0.000)	**P(-5)** -0.6065 (P: 0.092)	--	0.14	0.29
E2025 (8)	-0.1590 (P: 0.441)	**P(-3)** 0.1570 (P: 0.235)	**P(-5)** -0.1105 (P: 0.401)	0.9726 (P:0.000)	1.38	0.96

Note: Detrended series as explained in the text.

IV. Conclusion

Industrialization was a long process but the breakthrough of modern industry in Sweden started about 1890. It is reasonable to assume that the expansion of primary education a decade earlier paved the ground for the rapid development that encompassed, more or less, all sectors of the society. The present explorative analysis of enrolment in education and productivity change has not, however, been able to justify that assumption. Nor has the hypothesis been rejected; the employed tools may be too coarse. On the other hand, for the postwar period a double directed relation was found for enrolment in compulsory education and productivity, and the relation between education and growth may be seen as fundamentally a cumulative process.

Yet, considering secondary and higher education changes in enrolment preceded productivity change during the whole century and in particular during the second half. This pattern is more unambiguous for higher than for secondary education. Productivity change, and economic growth, can therefore not be said to have caused expansion of secondary education. The opposite causation, from secondary and higher education, though, seems reasonable.

The analysis here has been pursued at a rather aggregate level, both as regards productivity data and enrolment. A task for further research is to look at different specialist education and also to look for other measures of economic performance than productivity in manufacturing. Then it may be possible to disentangle between the role of general education, and specialist and vocational education, respectively. Even more desirable is that such research could be performed in comparative perspective, since only if the same time patterns appear in different countries general conclusions can be drawn.

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